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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : H04J 3/16, H04Q 7/00, 9/00 H04M 11/00	**A1**	(11) International Publication Number: **WO 91/00660** (43) International Publication Date: 10 January 1991 (10.01.91)

(21) International Application Number: PCT/US90/03570

(22) International Filing Date: 22 June 1990 (22.06.90)

(30) Priority data:
371,764   26 June 1989 (26.06.89)   US

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(81) Designated States: AT (European patent), AU, BE (European patent), CA, CH (European patent), DE (European patent)*, DK (European patent), ES (European patent), FR (European patent), GB (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent).

Published
With international search report.

(54) Title: SYNCHRONIZATION AND EQUALIZATION IN A TDMA CELLULAR SYSTEM

(57) Abstract

In a Time Division Multiple Access (TDMA) cellular system, there is provided a mechanism for synchronization and equalization comprising: providing synchronization information (S/S) sufficiently removed from the start of a TDM slot so as to maintain the integrity of that synchronization information (S/S) at adjacent cells and providing that synchronization information (S/S) not so far removed from the start of the slot as to necessitate adaptive equalization of information preceding the synchronization information (S/S) for sufficiently reliable recovery. The equalization is further enhanced by providing, roughly midway between the synchronization information (S/S) and the end of the slot, additional information (CC) upon which equalization may retrain. Accordingly, equalizers perform retrospective, non-adaptive equalization of information preceding the synchronization information (S/S), perform adaptive equalization of information following that synchronization information (S/S), and retrain utilizing known bit-sequences elsewhere within the TDM slot; the additional information (CC) comprises known bit-sequences identifying cells.
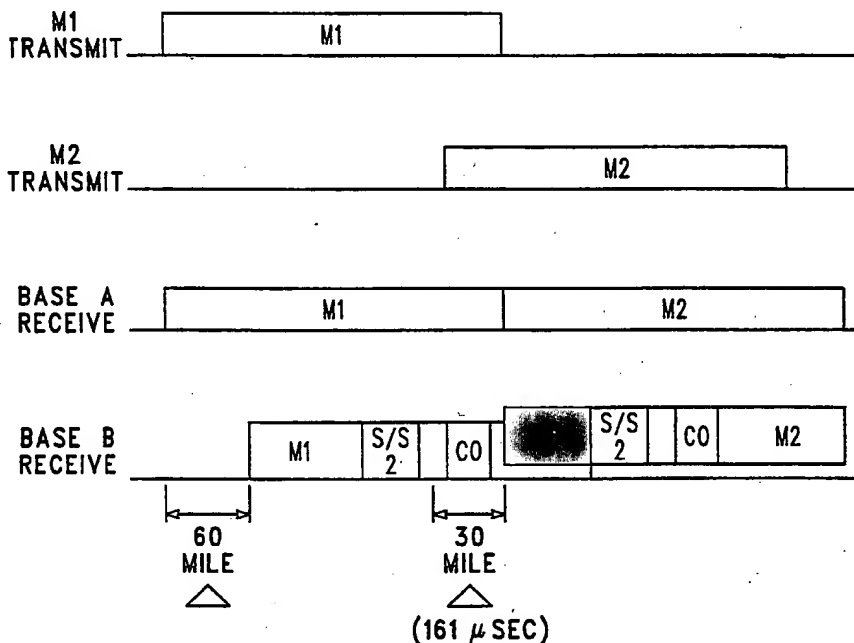
DESIGNATIONS OF "DE"

Until further notice, any designation of "DE" in any international application whose international filing date is prior to October 3, 1990, shall have effect in the territory of the Federal Republic of Germany with the exception of the territory of the former German Democratic Republic.

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Synchronization and Equalization in a TDMA Cellular System

The Field of Invention

5   This invention is concerned with synchronization and equalization.

More particularly, this invention is concerned with system synchronization and equalization in a Time Division Multiple Access (TDMA) cellular system.

Background of the Invention

10   In land-mobile Time Division Multiple Access (TDMA) wireless systems, where the arrival times of subscriber transmissions must be arranged in time with the cell synchronization (advanced or retarded) to account for differing propagation delays due to the mobility of the subscriber, synchronization

15   information must be provided to the subscriber to acquire and maintain all transmissions synchronized into the Time Division Multiplexed (TDM) slot structure of the communications channel.

One way is to provide sufficient guard time before the

20   subscriber transmission of any useful information to accommodate the furthest expected transmission. Then, that subscriber is commanded to advance its subsequent transmissions to become synchronous with the cell. Known synchronizing sequences are incorporated within all

25   transmissions and used for maintaining cell synchronization.

The problem in cellular TDMA systems is that adjacent cells must aperiodically monitor subscribers in neighboring cells for

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handoff candidacy (as the subscriber moves from cell to cell).
Thus, as illustrated in Figure 1, when subscribers have been
synchronized to their host cell (taking account of their
respective range from the host), subscriber transmissions are
5   out of synchronism with those of adjacent cells (because of the
probable opposite relationship of their ranges from the
adjacent cell site). For example, if Mobile subscriber 2 (M2)
has its transmissions advanced (as in Figure 2b) by eight bits
(at 48 Kbps - kilobits per second) to account for the thirty mile
10   difference in range from cell site A in order to arrive in time
slot 2 following (Figure 2c) that of Mobile subscriber 1 (M1),
Figure 2a, M2's transmissions will have advanced toward M1's.
Yet, for adjacent cell B, M1's transmissions should have been
advanced toward M2's to accommodate the differences in their
15   respective ranges from cell site B. Accordingly, the end of M1's
transmissions in time slot 1 will collide with the beginning of
M2's transmissions in time slot 2 as received by cell site B (as
illustrated by the hatched area of Figure 2d). Thus,
synchronizing information (the information of interest to the
20   adjacent cell) cannot appear at the start of a time slot, or it will
be subject to collision (in the hatched area of Figure 2d).

Wireless transmissions reflect off numerous objects and
obstructions on their way to the receiver. As a result, for
proper detection of the individual bits of information
25   transmitted, equalizers must align in time the various time-
dispersed echoes it receives and make decisions about each bit.
Accordingly, the receiver correlates the synchronization
sequence present within each echo against a known sequence
and, having the instant of correlation of each echo, is able to
30   align them in time and obtain time-dispersal coefficients for
equalization. Having the instant of correlation and the time-
dispersal function, it is possible to detect subsequent
information (and to retrospectively detect preceding
information, if stored) until the propagation conditions change

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and alter the time-dispersal characteristics. Adaptive
equalization, although computationally intensive, adapts the
coefficients to track the time-dispersal characteristics over
time; the longer the time (measured by number of bits) since
5   the arrival of the synchronization/equalization sequence, the
greater the need for adaptive equalization. A more extensive
discussion of adaptive equalization can be found in: *Shahid
Qureshi, Adaptive Equalization, IEEE Communications Magazine,
March 1982, 0163-6804/82/0300-0009, pp. 9-16.*

10   The Pan-European Digital Cellular system is a TDMA cellular
system that employs a mid-amble -- synchronizing information
appears in the middle of the time slot. Our problem never
arose there because fixed equalization at their data rate and
slot length is adequate for reliable detection in both the
15   forward time direction and the reverse time direction.
However, at our data rate and slot length, *adaptive* equalization
would be required for reliable detection in the reverse time
direction, adding substantially to the complexity of the
equalizer and requiring a sizeable memory to store the time-
20   dispersed echoes preceding the synchronization sequence.

This invention takes as its object to overcome these
shortcomings and to realize certain advantages presented
below.

SUMMARY OF THE INVENTION

25   In a Time Division Multiple Access (TDMA) cellular system,
there is provided a mechanism for synchronization and
equalization comprising: providing synchronization information
sufficiently removed from the start of a TDM slot so as to
maintain the integrity of that synchronization information at
30   adjacent cells and providing that synchronization information
not so far removed from the start of the slot as to necessitate

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adaptive equalization of information preceding the
synchronization information for sufficiently reliable recovery.

The equalization is further enhanced by providing, roughly
midway between the synchronization information and the end
5   of the slot, additional information upon which equalization may
retrain.

Accordingly, equalizers perform retrospective, non-adaptive
equalization of information preceding the synchronization
information, perform adaptive equalization of information
10   following that synchronization information, and retrain utilizing
known bit-sequences elsewhere within the TDM slot; the
additional information comprises known bit-sequences
identifying particular cells.

DESCRIPTION OF THE DRAWINGS

15   Additional objects, features and advantages of the invention
will be more clearly understood and the best mode
contemplated for practicing it in its preferred embodiment will
be appreciated (by way of unrestricted example) from the
following detailed description, taken together with the
20   accompanying drawings in which:

Figure 1 is a graphic illustration of the problem solved by this
invention and the environment in which the preferred
embodiment of the invention operates.

Figures 2a through 2d are timing diagrams of the problem
25   encountered and the solution offered by the preferred
embodiment of the invention.

One of any number of exemplary embodiments of such an
apparatus is illustrated in US Pat. No. 4,829,543 to Borth et al.

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and assigned to Motorola, the instant assignee, and reproduced herein as a prior art figure for the convenience of the reader.

DETAILED DESCRIPTION

5   This invention recognizes that, by positioning synchronization information (S/S) sufficiently beyond the start of the TDM slot, the integrity of the synchronization information will be maintained and will not be collided with by the end of the previous slot (the hatched area of Figure 2d). Moreover, positioning the synchronization as far forward as is consistent

10   with avoiding collision allows any retrospective detection of data to be done by a fixed coefficient equalizer rather than an adaptive equalizer. This is far less computationally intensive and substantially reduces the memory requirements (because far less information must be retained for retrospective

15   processing).

In the preferred embodiment of the invention, synchronization information is provided sixteen bits (2 radii of range difference at 30 miles at 48 Kbps) after the start of the time slot (i.e., just beyond the hatched area of Figure 2d), which provides the   -

20   extra guard time required at the adjacent cells. Thus, only sixteen bits need be stored for retrospective processing (thereby substantially reducing memory requirements) and, since the time-dispersal characteristics are far less likely to change significantly over that sixteen-bit interval, the necessity

25   for retrospective *adaptive* equalization is eliminated (thereby substantially reducing the complexity of the equalization). Control information (information that is unimportant to the adjacent cell) is transmitted in the beginning sixteen bits of the slot.

30   As further improvement, known bit-sequence identifying the host cell (CC -- "color code" or Digital Supervisory Audio Tone -

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DSAT) that are regularly exchanged as an integral part of all transmissions can be transmitted somewhat later in the slot -- somewhere (avoiding the hatched area of Figure 2d) -- such that it also is available to the adjacent cell. So placed, it would

5   be useable for retraining the adaptive equalizer as it correlates on the sequence; for that purpose, perhaps somewhere midway between the synchronization sequence and the end of the slot would be optimal.

An attendant advantage of such a *separate* cell identification

10   field is that the field may be readily detected without decoding of other parts of the transmission (e.g., the digitized voice message or error correction information). Thus, this field can be readily utilized by rudimentary, nonvoice-capable scanning receivers (for confirmation of the candidacy of a subscriber for

15   handoff), resulting in substantial hardware and processing simplification. Moreover, this field, received intact due to its advantageous position within the time slot, can be readily utilized for positive muting (voice muting) of co-channel interferers (with different "color codes") that would otherwise

20   result in inadvertent reconstruction of voice messages from other cells.

The attendant advantages of this invention include elimination of retrospective *adaptive* equalization (and its concomitant computational penalties) and a substantial reduction in

25   memory requirements.

In a Time Division Multiple Access (TDMA) cellular system, there has been provided a mechanism for synchronization and equalization comprising: providing synchronization information sufficiently removed from the start of a TDM slot so as to

30   maintain the integrity of that synchronization information at adjacent cells and providing that synchronization information not so far removed from the start of the slot as to necessitate

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adaptive equalization of information preceding the synchronization information for sufficiently reliable recovery.

The equalization has further been enhanced by providing, roughly midway between the synchronization information and the end of the slot, additional information upon which equalization may retrain.

5

Accordingly, equalizers perform retrospective, non-adaptive equalization of information preceding the synchronization information, perform adaptive equalization of information following that synchronization information, and retrain utilizing known bit-sequences elsewhere within the TDM slot; the additional information comprises known bit-sequences identifying particular cells.

10

The foregoing discussion is only meaningful for subscriber-to-system communication as only those are of interest at the adjacent cell.

15

The means for implementing the invention presented above are easily constructed and well understood by those ordinarily skilled in this field. One of any number of exemplary embodiments of such an apparatus is illustrated in US Pat. No. 4,829,543 to Borth et al. and assigned to Motorola, the instant assignee, and reproduced herein as a prior art figure for the convenience of the reader. While the preferred embodiment of the invention has been described and shown, it will be appreciated by those skilled in this field that other variations and modifications of this invention may be implemented; these and all other variations and adaptations are expected to fall within the ambit of the appended claims.

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Synchronization and Equalization in a TDMA Cellular System

Claims

What we claim and desire to secure by Letters Patent is:

5 1.   A method of synchronization and equalization in a Time
        Division Multiple Access (TDMA) cellular system
        comprising:

              providing synchronization information removed from
                    the start of a TDM slot so as to avoid collisions of
10   that synchronization information at adjacent
                    cells

              and providing that synchronization information not so
                    far removed from the start of the slot as to
                    involve adaptive equalization of information
15   preceding the synchronization information.

    2.   A method as claimed in Claim 1 above, further
        comprising:

              providing subsequent additional information not
                    subject to collision at adjacent cells upon which
20   equalization may retrain.

    3.   A method as claimed in Claim 2 above, wherein the
        additional information is provided about a point midway
        between the synchronization information and the end of
        the slot.

25 4.   A method as claimed in Claim 2 above, wherein the
        additional information comprises bit-sequences
        identifying cells.

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5.   A method as claimed in Claim 4 above, wherein the bit-sequences are utilized for confirming handoff candidacy.

6.   A method as claimed in Claim 4 above, wherein the bit-sequences are utilized for voice muting.

5   7.   A method of synchronization and equalization in a Time Division Multiple Access (TDMA) cellular system comprising:

       providing synchronization information removed from the start of a TDM slot so as to avoid collision of that synchronization information at adjacent cells,

10

       providing that synchronization information not so far removed from the start of the slot as to involve adaptive equalization of information preceding the synchronization information

15

    and providing subsequent additional information not subject to collision at adjacent cells upon which equalization may retrain.

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8. A method of synchronization and equalization in a Time
Division Multiple Access (TDMA) cellular system
comprising:

5   providing synchronization information removed from
the start of a TDM slot so as to avoid collision of
that synchronization information at adjacent
cells,

               providing that synchronization information not so far
removed from the start of the slot as to involve
10   adaptive equalization of information preceding
the synchronization information

               and providing, about a point midway between the
synchronization information and the end of the
slot, additional information upon which
15   equalization may retrain.

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9. A method of synchronization and equalization in a Time Division Multiple Access (TDMA) cellular system comprising:

performing retrospective, non-adaptive equalization of information preceding the synchronization information

and performing adaptive equalization of information following that synchronization information.

10. A method as claimed in Claim 9 above, further comprising:

retraining the adaptive equalization utilizing known bit-sequences elsewhere within the TDM slot.

11. A method as claimed in Claim 10 above, wherein the known bit-sequences comprise sequences identifying cells.

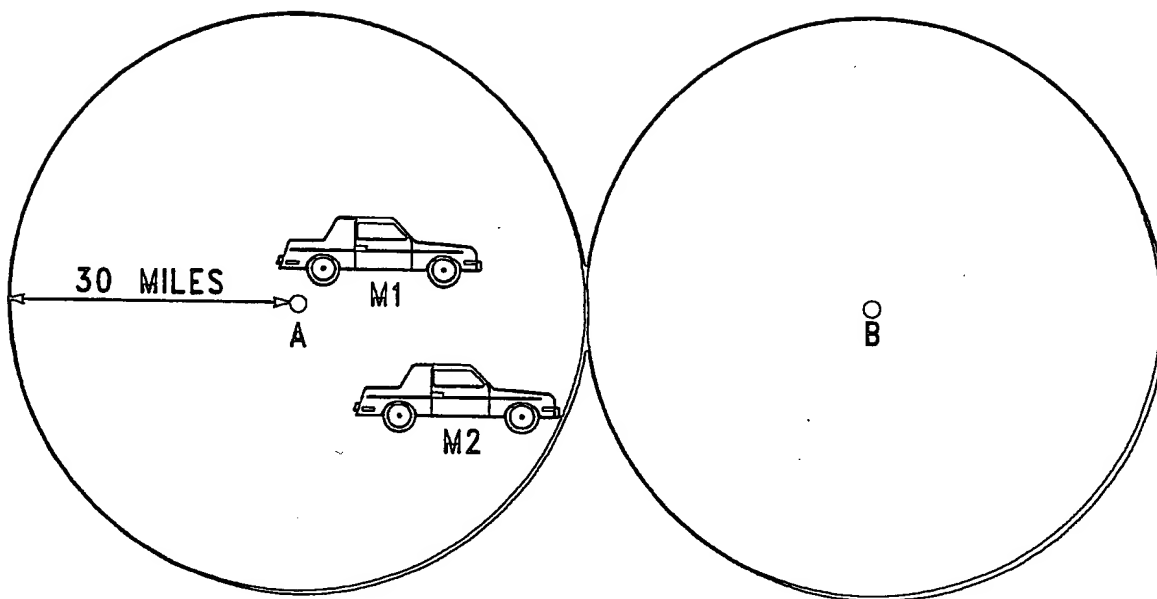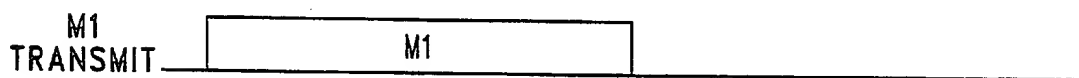12. A method of synchronization and equalization in a Time Division Multiple Access (TDMA) cellular system comprising:

performing retrospective, non-adaptive equalization of information preceding the synchronization information,

performing adaptive equalization of information following that synchronization information

and retraining the adaptive equalization utilizing known bit-sequences elsewhere within the TDM slot.

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13. An apparatus for synchronization and equalization in a Time Division Multiple Access (TDMA) cellular system comprising:

 means for performing retrospective, non-adaptive equalization of information preceding the synchronization information

 coupled with means for performing adaptive equalization of information following that synchronization information.

14. An apparatus as claimed in Claim 13 above, further comprising:

 coupled with the adaptive equalization means, means for retraining the adaptive equalization utilizing known bit-sequences elsewhere within the TDM slot.

15. An apparatus as claimed in Claim 14 above, wherein the known bit-sequences comprise bit-sequences identifying cells.

F I G . 1

F I G . 2 A

M1
TRANSMIT | M1 |

F I G . 2 B

M2
TRANSMIT | M2 |

F I G . 2 C

BASE A
RECEIVE | M1 | M2 |

F I G . 2 D

BASE B
RECEIVE | M1 | S/S 2 | CO | ▉ | S/S 2 | CO | M2 |
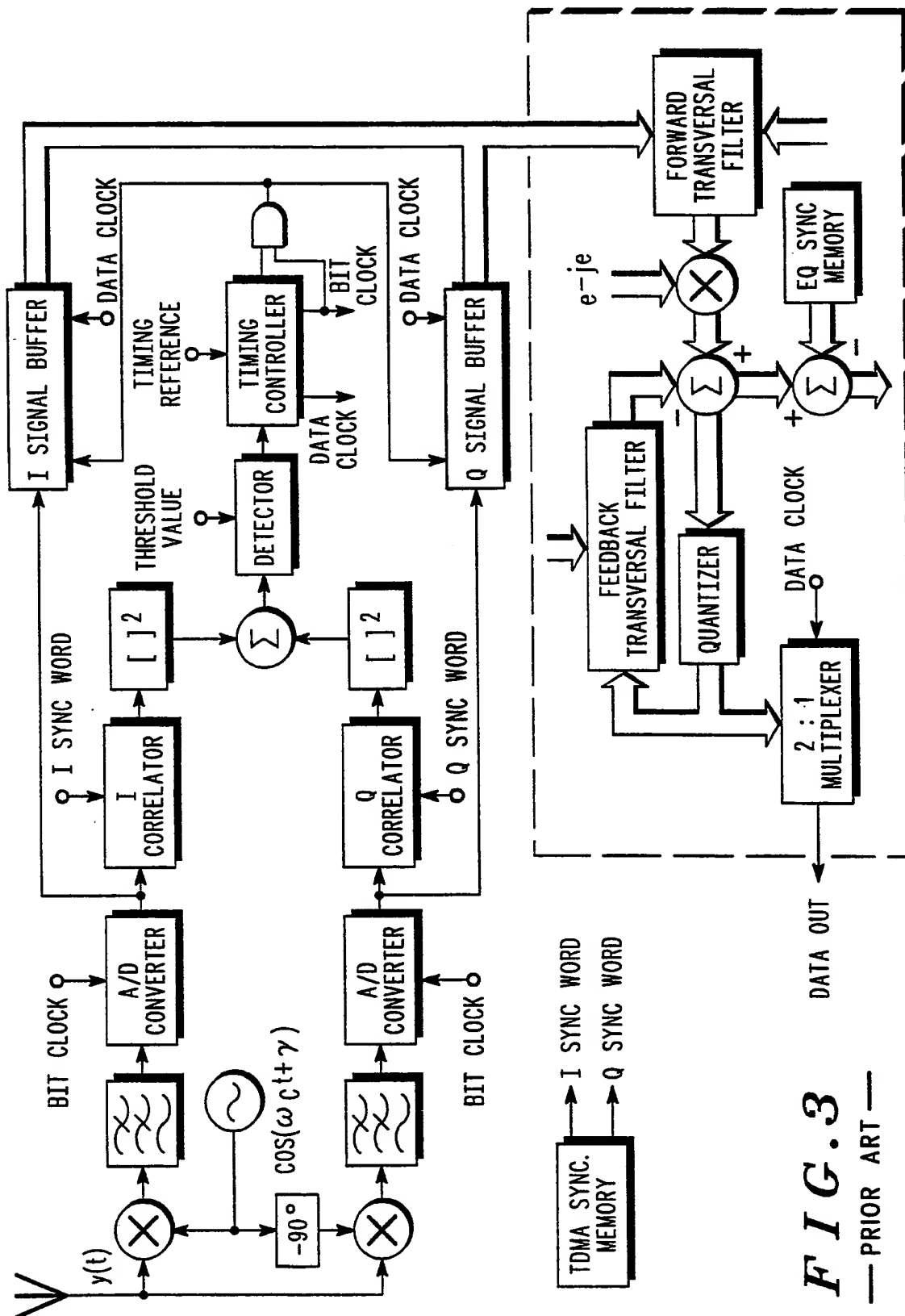
60 MILE

30 MILE

(161 μ SEC)
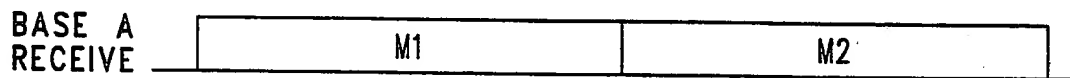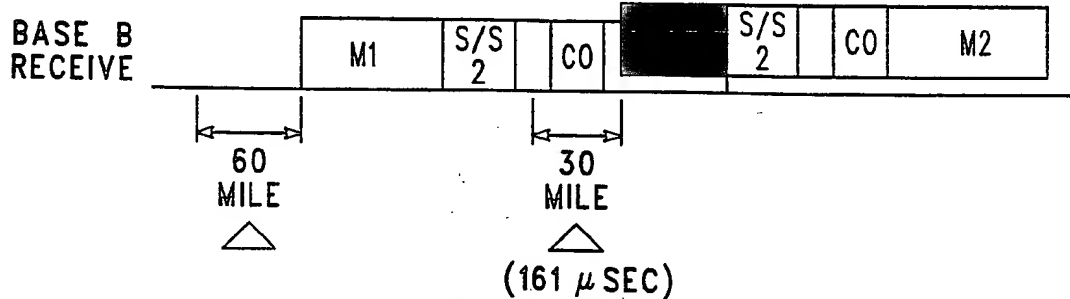
FIG. 3
— PRIOR ART—

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US90/03570

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): H04J 3/16; H04Q 7/00; H04Q 9/00; H04M 11/00
U.S.Cl.: 370/95.3; 455/33; 379/60

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
U.S.Cl.	370/95.1,95.3,100.1,104.1,105,105.1,110.1,111 379/59,60,63; 455/33,38,54; 375/107,108

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched 8

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category *	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No. 13
A	US, A, 4,829,543 (BORTH et al.) 09 May 1989. See entire document.	9-15
A	US, A, 4,754,453 (EIZENHÖFER) 28 June 1988. See entire document.	1-8
A	US, A, 4,414,661 (KARLSTROM) 08 November 1983. See entire document.	1-8
A	US, A, 4,252,999 (ACAMPORA et al.) 24 February 1981. See entire document.	1-8

* Special categories of cited documents: 10

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

26 July 1990

Date of Mailing of this International Search Report

02 OCT 1990

International Searching Authority

ISA/US

Signature of Authorized Officer

Alpus H. Hsu   NGUYEN NGOC-HO INTERNATIONAL DIVISION

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